

REMARKS

Reconsideration and allowance of this application, as amended, is respectfully requested.

This Amendment is in response to the Office Action dated October 1, 2004. Appreciation is expressed for the allowance of claims 14 and 15.

By the present Amendment, each of the independent claims 1, 3, 5, 8, 10, 16, 17 and 19 has been amended to clarify the invention as will be discussed below.

Briefly, the present invention is directed to an improved polycrystalline semiconductor thin film structure which has superior characteristics by virtue of the feature that, for any "optional" crystal grain, "the number of crystal grains with the number of closest crystal grains of 6 is greatest among plural crystal grains that form the polycrystalline semiconductor thin film." e.g. referring to the language of claim 1). This was discussed at length in the last Amendment filed on July 8, 2004. An example of such a structure is shown in Fig. 9(b), wherein, for a central optional crystal grain 251, the number of closest crystal grains is 6. Figs. 6(a)-(c) also show the features of a layer of polycrystalline constructed with a plurality of crystal grains (such as shown in Fig. 9(b)), having this same feature.

By the present Amendment, the features discussed on page 22 of the specification are now defined in each of the claims. More specifically, as noted on page 22, line 7 et seq., laser irradiation is repeated so that crystal grains change from the arrangement shown in Fig. 9(a) to the final arrangement shown in Fig. 9(b). As noted on page 22, line 7:

"In the first laser irradiation, when laser beam irradiation is applied repeatedly by once or predetermined number of cycles, hexagonal crystal grains are formed successively as crystal grains and, subsequently, they continue to rotate or move as shown in Fig.

9(a) and then respective sides of adjacent hexagonal crystal grains meet each other as shown in Fig. 9(b)."

As further noted on page 22, line 17 et seq.:

"As shown in Fig. 9(a), even when smaller crystal grain 1001 is formed between the hexagonal crystal grains 251, it is joined with large hexagonal crystal grains 251 at the periphery and eliminated in the step of the first laser irradiation and the step of the second irradiation applied repeatedly."

Thus, the desired product shown in Fig. 9(b) is only formed after a plurality of laser irradiation steps are carried out to change a structure such as shown in Fig. 9(a) into a final product such as shown in Fig. 9(b).

Reconsideration and removal of the rejection of claims 1-6, 10, 11 and 16-20 as being anticipated by Yamazaki, the rejection of claim 7 as being anticipated by Kusumoto and the rejection of claims 8, 9, 12 and 13 as being obvious over Kusumoto in view of Yamazaki is respectfully requested. By the present Amendment, each of the independent claims has been amended to specify:

"wherein the polycrystalline semiconductor thin film is formed by a plurality of laser irradiation steps, wherein the laser irradiation steps are carried out so that, after the last laser irradiation step, the number of crystal grains with the number of closest crystal grains of 6 is greatest among plural crystal grains that form the polycrystalline semiconductor thin film."

As such, the feature discussed above with regard to the formation of a polycrystalline thin film structure such as shown in Fig. 6(a)-6(c) and Fig. 9(b), utilizing repeated laser irradiation, is now clearly set forth in each of the independent claims. Regarding this, it is noted that the recited features of forming the polycrystalline semiconductor thin film using the repeated laser irradiation represents an improved product (i.e., a polycrystalline silicon film in which the number of closest crystal

grains is 6 is greatest among plural crystal grains that form the film). As noted in the case of In re Luck, 171 USPQ 523:

"As for the method of application, it is well established that product claims may include process steps to wholly or partially define the claimed product...To the extent these process limitations distinguish the product over the prior art, they must be given the same consideration as traditional product characteristics."

Accordingly, it is respectfully submitted that the present independent claims clearly define over the cited prior art since neither Yamazaki nor Kusumoto, whether considered alone or in combination with one another, teach or suggest the use of plural laser irradiation steps to form an improved product.

Turning first to the primary reference to Yamazaki, as will be discussed in detail below, this reference forms a silicon semiconductor thin film using a completely different technique than the laser irradiation steps defined by the present claims. As a result (and as will be explained in detail below), the structure shown in Fig. 2A in Yamazaki is only a temporary structure which exists during the formation of a final product which is the stripe-type large crystal grain product shown in Figs. 2B and 2C. Therefore, Yamazaki fails to meet the present claim limitations of the product formed following the last of a plurality of laser irradiation steps to have a claimed crystal grain structure.

More specifically, an object (or purpose) of Yamazaki's invention is to make the crystal structure of a silicon semiconductor thin film substantially single crystal and to use the substantially single crystal area for the active area of the semiconductor device. As means for achieving the object, the following crystal growth technology is used (See Figs. 1A to 1F, lines 1-64, column 7).

The initial structure for crystal growth is characterized by forming an a-Si film on a SiO₂ underlayer with asperity and spin-coating a nitrate liquid containing Ni on the a-Si film. This characteristic structure described above undergoes the four steps as follows:

In a first step, the structure is heated up to about 500 to 700°C within an inert gas to diffuse the Ni present at the upper-most layer up to an interface layer between the a-Si film and the SiO₂ layer.

In a second step, Ni reaching the a-Si/SiO₂ interface is diffused in the a-Si/SiO₂ interface to segregate on the asperity of SiO₂.

In a third step, when Ni segregating on the asperity area of SiO₂ and Si are formed into silicide, the so-called crystal core is formed. The silicide surface becomes a growth surface and the crystal grows vertically. As a result of completion of the vertical growth of crystal, either a column or needle-like crystal is formed. This column-like crystal is a core crystal that will grow laterally later. This type of core crystal utilizing nickel silicide is characterized in that (111) plane is a stable plane of the growth plane (lines 48-52, col. 8). Thus, the side surfaces of the column-like crystal are enclosed by (111) planes. For this reason, the shape of the crystal becomes hexagonal (as also pointed out by the Examiner).

Lastly in a fourth step, the crystal growth proceeds laterally from a starting point, i.e., a side surface having a (111) crystalline surface of the column-like crystal formed at the third step, forming a (stripe-shaped) large crystalline grain (Fig. 2B). The crystalline grain size depends on striking against the adjacent lateral-grown crystalline grains.

In the meantime, the describing of the generalization of silicon crystal growth from molten liquid of bulk through a CZ process is helpful in clarifying a difference between Yamazaki's invention and the applicant's invention.

For formation of a crystalline state from an amorphous state, the following steps are required.

1. When a substance is brought into a supercooled state, a crystalline core is formed from a non-uniform state as a starting point. For silicon, its diameter is several nm and it has a polygonal structure enclosed by a plurality of crystalline surfaces;

2. A crystalline growth starts from the side surface of this crystal core. A crystal growing speed and a surface energy are dependent on a crystalline surface. Thus, a crystal having a preference orientation can be formed by properly controlling a growth temperature and a cooling speed.

3. This crystal used as a core crystal is brought into contact with a silicon-molten liquid, subjected to necking (the crystal is oriented), and then pulled up therefrom, thus forming a single-crystal.

In other words, in accordance with the existing crystal growth technology, it is taught that formation of the single-crystal needs the steps of formation of the crystal core, growth of the core crystal and growth of the crystal. The applicant understands that Yamazaki's invention also depends on this principle and is a skilful method for realizing crystal growth control by use of a Ni catalyst. That is, the aforesaid first second steps correspond to the formation of the crystalline core, the third step corresponds to growth of the core crystal and the fourth step corresponds to the crystal growth. The formation of the crystal core and multi-crystal grains is realized

through a solid phase growing technology. Further, for the crystal growth, additional laser heating improves crystallization through liquid phase growth. Yamazaki's invention is most characterized by forming the SiO₂ underlayer with asperity, allowing Ni to segregate on the SiO₂ asperity (core formation), and forming a core crystal in which a crystalline orientation on the side surface, which the feature of suicide on the growth surface, is (111) plane. As a result, a hexagonal crystal (which is the center of the discussion) is formed. In accordance with the specification of Yamazaki, the fact that the side surface has a crystalline plane of (111) plane has an effect of enhancing crystallinity (increased diameter grain) due to the lateral growth from the plane at the fourth step. The applicant's interpretation shows that the hexagonal column-like crystal is a core crystal, so that upon completion of the lateral growth at the fourth step, it is taken into the stripe-like large crystalline grains each growing in a lateral direction and it is hard to observe in the form of the final semiconductor thin film. That is, the hexagonal crystalline grain of Yamazaki is a mere temporary form for forming the stripe-type large crystalline grain illustrated in Figs. 23 and 2C.

In contrast, the applicant's invention does not utilize the solid phase growth, but uses a molten crystallization process with laser radiation. As the laser radiation, an excimer laser with several ns pulse is used for the laser radiation. The molten crystallization process is characterized in that laser radiation with proper fluence instantly melts a-Si and completes the crystallization within 100 ns. That is, the generation of the crystal core, the formation of the seed crystal and the crystal growth occur within 100 ns. Because of this, the present technology prohibits the form of the seed crystal from being observed. Only the form of the multi-crystal semiconductor film whose crystal growth has been completed can be observed.

Since the Yamazaki's solid phase growth technology requires several hours for forming the seed crystal, the form of the seed crystal can be evaluated on the way of the processes. If the Yamazaki's technology is compared with the present invention in terms of the crystallization, the comparison should be made at the final state of the semiconductor film at the step where the crystal growth is completed. In Yamazaki's semiconductor film, the positional control is performed on the large crystalline grain, so that an element active region can be formed into a single-crystal state. In turn, the applicant's invention utilizes the multi-crystal thin film having a largest number of the closest crystalline grain 6 in order to suppress the variations in performance of many elements. The active area of the element is not necessarily single-crystal. Thus, it is quite difficult to estimate the present invention in view of the Yamazaki's invention.

Further, as pointed out by the Examiner, even if 201 in Yamazaki is assumed to be a crystal grain having the closest crystalline grain number 6, the semiconductor thin film that can be assumed to be a Yamazaki's final single crystal does not contain the largest number of crystal grains with the closest crystal grain number 6. As described above, the Yamazaki's hexagonal crystal is a seed crystal for use in forming the stripe-like large crystal. In contrast, the hexagonal crystal grain of the applicant's invention (the closest crystal grain is 6) is the crystal grains present in the final semiconductor thin film following the last of a plurality of laser irradiation steps. In addition, the semiconductor thin film containing the largest number of it has an effect in reducing variations in performance of each semiconductor device of the present invention. Accordingly, reconsideration and allowance of the amended claims over Yamazaki is respectfully requested.


With regard to the Kusumoto reference, although this reference is of general interest, nothing in this reference provides any suggestion of modifying Yamazaki to overcome the above-noted shortcomings of that reference. Nor does Kusumoto teach or suggest the claimed features noted above concerning the formation of the improved product using a plurality of laser irradiation steps. Therefore, reconsideration and allowance of the pending claims over the Kusumoto reference, whether considered alone or in combination with Yamazaki, is respectfully requested.

If the Examiner believes that there are any other points which may be clarified or otherwise disposed of either by telephone discussion or by personal interview, the Examiner is invited to contact Applicants' undersigned attorney at the number indicated below.

To the extent necessary, Applicants petition for an extension of time under 37 CFR 1.136. Please charge any shortage in fees due in connection with the filing of this paper, including extension of time fees, to the Antonelli, Terry, Stout & Kraus, LLP Deposit Account No. 01-2135 (Docket No. 520.41003X00), and please credit any excess fees to such Deposit Account.

Respectfully submitted,

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